Morphological characterization of striped seabream (*Lithognathus mormyrus*, Sparidae) in some Mediterranean lagoons

by

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Abstract. – Morphological variation of *Lithognathus mormyrus* (Linnaeus, 1758) samples harvested in six Mediterranean lagoons was investigated using 23 truss elements and 11 conventional linear measurements. Multivariate analyses revealed a highly significant morphological discrimination between western Mediterranean basin samples (lagoons of Bizerta, Ghar El Melh and Mellah) that differ from each other but are also differentiated from the oriental lagoon samples (lagoons of El Biban, Farwa and Venice) by some variables, which are related to the head length. Thus, our findings highlighted the peculiarity of the Mellah lagoon specimens (Algeria), which have the smallest heads compared to the other samples. This morphological variation seems to be associated to various constraints represented by the feeding strategy, and availability, type and size of ingested prey. As for the oriental specimens, they tended to cluster. However, significant differences, related to the caudal peduncle length, were detected, especially between El Biban specimens and those of Farwa and Venice lagoons. This morphological variation appears to be primarily associated to hydrodynamic constraints. The morphological divergence among the various studied samples is suggested to be environmentally-induced (phenotypic plasticity).

Résumé. – Caractérisation morphologique de populations de *Lithognathus mormyrus* (Sparidae) dans quelques lagunes méditerranéennes.

La variabilité morphologique d'échantillons de *Lithognathus mormyrus* (Linnaeus, 1758), collectés dans six lagunes méditerranéennes, a été analysée au moyen de 23 éléments de truss et 11 mesures linéaires conventionnelles. Les analyses multivariées ont montré une discrimination morphologique, hautement significative, entre les échantillons du bassin occidental de la Méditerranée (lagunes de Bizerte, de Ghar El Melh et de Mellah) qui diffèrent les uns des autres mais se distinguent aussi des spécimens lagunaires orientaux (lagunes d'El Biban, de Farwa et de Venise) par certaines variables qui sont liées à la longueur de la tête. Ainsi, les résultats obtenus ont fait ressortir la particularité des spécimens de l'échantillon de la lagune de Mellah (Algérie) présentant des têtes petites. Cette divergence morphologique semble être liée à différentes contraintes, représentées par la stratégie d'alimentation, et par la disponibilité, le type et la taille des proies ingérées. Les échantillons orientaux ont montré une tendance à se regrouper. Toutefois, des différences significatives, liées à la longueur du pédoncule caudal, ont été décelées, et particulièrement entre l'échantillon d'El Biban et ceux de Farwa et de Venise. Cette variation semble être principalement liée à des contraintes hydrodynamiques. La divergence morphologique, entre les divers échantillons étudiés, est suggérée comme étant écologiquement induite (plasticité phénotypique).

The striped seabream, *Lithognathus mormyrus* (Linnaeus, 1758), is a demersal marine fish belonging to the family Sparidae. It is a gregarious species living on various types of sea bottoms in the Atlantic Ocean, the Mediterranean and Red Seas and in the southwestern Indian Ocean, including sandy and rocky bottoms and sea grass beds at depths ranging from 0 m to 150 m, but predominantly between 10 m and 30 m deep (Bauchot and Hureau, 1986, 1990). *L. mormyus* is also frequently encountered in lagoons and estuaries along the Mediterranean coasts (Matić-Skoko *et al.*, 2007; Monteiro *et al.*, 2010). After sea spawning period, young individuals enter into lagoons (Suau, 1970), which are known

to provide essential habitats such as nursery zones for many fish species (Emre *et al.*, 2010).

Coastal lagoons are dynamic ecosystems characterized by physical features such as shallowness, relative isolation from the open sea due to the coastal barriers that maintain some communication channels and the presence of boundaries with strong physical and ecological gradients (Unesco, 1981; Pérez-Ruzafa *et al.*, 2007). Along the Mediterranean coastline, they are numerous and have mostly appeared during the Holocene time period. According to Kjerfve (1994), the coastal lagoons are subdivided into three geomorphic types, i.e. choked, restricted and leaky, which correspond to

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three points along a spectrum reflecting the importance of the exchanges of water with the open sea. More generally, variability between lagoons is also attributed to the integration of a large set of biotic and abiotic factors criteria such as size, geomorphology, degree of isolation, bottom nature, salinity, temperature, etc. (e.g. Barnes, 1980; Guélorget and Perthuisot, 1983; Pérez-Ruzafa *et al.*, 2007). Estuaries and coastal lagoons represent important environments for fisheries and conservation, as they support high levels of fish production (McHugh, 1967; Elliott, 2002) and are used by large numbers of fish as nursery sites (Malavasi *et al.*, 2004; Çoban *et*

al., 2008). Moreover, these environments are considered to be naturally stressed systems with frequent disturbances and fluctuations (e.g. Pérez-Ruzafa *et al.*, 2007), which implies the definition of appropriate conservation strategies and the development of action plans for the sustainable use of both the biotic resources and the environment. That requires precise knowledge of the population structure of the species, particularly those of fishing interest.

As ever signaled, *Lithognathus mormyrus*, is present in numerous lagoons around the Mediterranean Sea and yet benefited from a few studies on morphological characteriza-
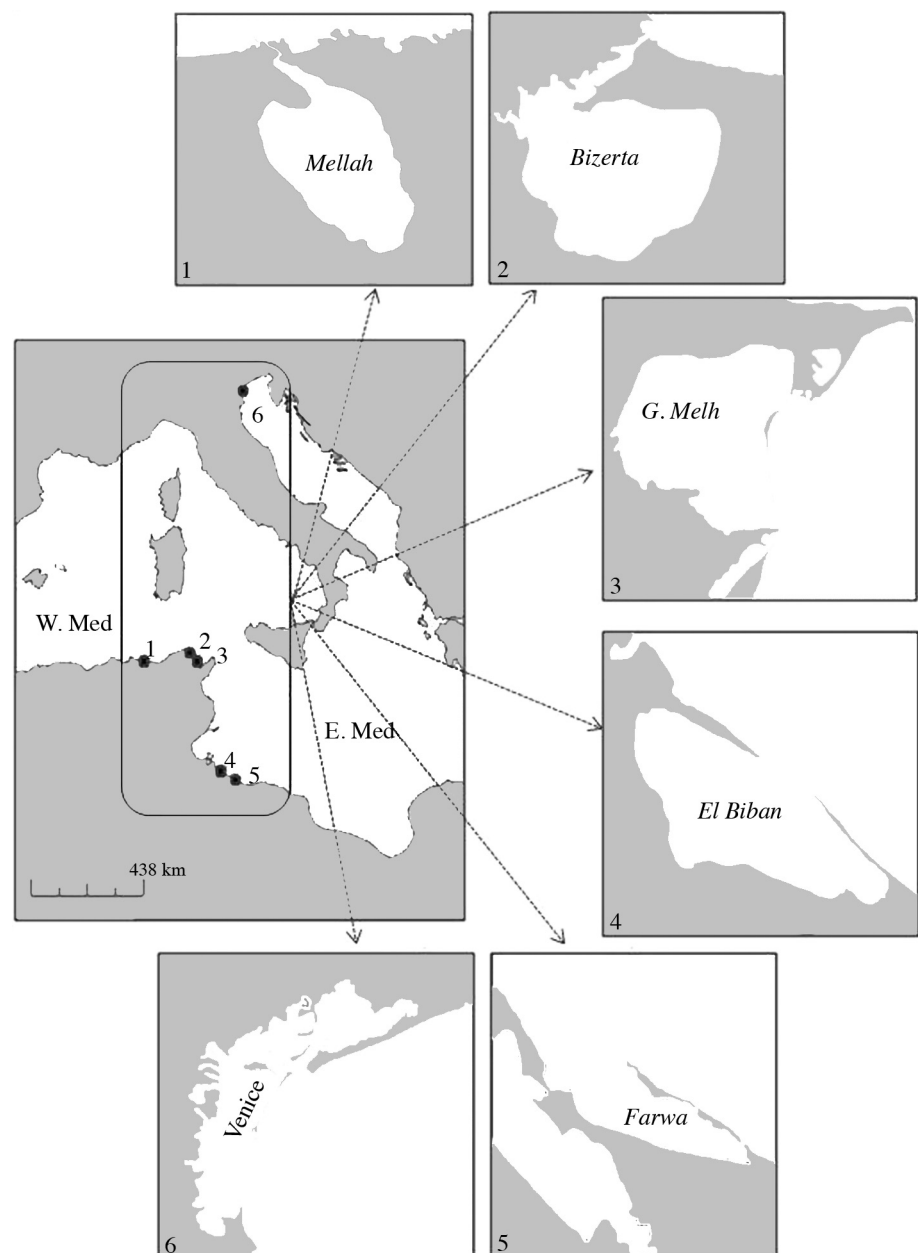

Figure 1. - Sampling localities of *Lithognathus mormyrus*: (1) Mellah lagoon (Algeria); (2) Bizerta lagoon (Tunisia); (3) Ghar El Melh lagoon (Tunisia); (4) El Biban lagoon (Tunisia); (5) Farwa lagoon (Libya); (6) Venice lagoon (Italy).

tion in this area. A significant degree of morphological dissimilarity between European Mediterranean samples of *L. mormyrus* was found but without showing a clear geographical gradient (Palma and Andrade, 2002). Moreover, this species has revealed a significant morphological divergence between lagoonal populations along the Tunisian coasts (Hammami *et al.,* 2011). These latter morphological results contrast with our knowledge on the genetic structure of the species, which shows only moderate differences between the lagoons at Bizerta (Northern Tunisia) and at El Biban (Southern Tunisia) (Hammami *et al*., 2007). These findings highlight the probable importance of the environmental component in shaping the species morphology, and are likely to have arisen from the phenotypic plasticity of fishes in response to differences in environmental factors (Wimberger, 1991, 1992). Indeed, during their early life stages, the morphology of fish species is particularly dependent on environmental conditions (Ryman *et al*., 1984; Cheverud, 1988) and fishes are considered to be phenotypically more variable than most other vertebrates (Carvalho, 1993). Thus, morphological structure of fish populations appears as an effective parameter to elucidate the phenotypic divergence between populations of fish species living in different habitats (Silva, 2003; Turan *et al.,* 2006; Mejri *et al*., 2012) and to identify the discreet phenotypic stocks and movement among geographically isolated populations (Roby *et al*., 1991; Palumbi, 1994; Uiblein, 1995; Hossain *et al*., 2010). In this regard, the lagoons are suitable places for comparing the morphological characters among fish populations.

In this paper we aim to define and compare further the morphological pattern of *L. mormyrus* from different lagoons, at the scale of the Mediterranean Sea, and explore the possible correlation between environmental parameters of the lagoons and the phenotypic differences between their populations. The morphology of adult specimens taken from six Mediterranean lagoons with different environmental features (Fig. 1: Mellah in Algeria, Bizerta, Ghar El Melh and El Biban in Tunisia, Farwa in Libya, and Venice in Italy) are investigated based on the analysis of the body shape using the truss network system (Strauss and Bookstein, 1982) and conventional linear measurements.

MATERIAL & METHODS

Collection sites (Fig. 1)

The six selected lagoons offer a diversity of environments that differ by their characteristics geomorphological, hydrological, hydrodynamic, physicochemical and by their biocenoses (Annex I). Three lagoons, Mellah (Algeria), Bizerta and Ghar El Melh (Tunisia), are located on the south shore of the western Mediterranean basin. Two lagoons, El Biban (Tunisia) and Farwa (Libya), are situated in the Gulf of Gabès (southern shore of eastern Mediterranean basin), which is of subtropical affinity (Bradai *et al*., 2004). And finally, the last lagoon, Venice (Italy) is located in the northern Adriatic (northern shore of eastern Mediterranean basin), which is of Subatlantic affinity (Giordani Soika, 1978) and exhibits some Indo-Pacific elements (Sacchi *et al*., 1985).

Sampling

A total of 188 specimens of striped seabream were collected. Samples were directly taken at the inshore inputs using the trammel nets and fish weir (Tab. I). Moreover, fish with low standard length were discarded to get rid of the allometric growth, characteristic of the early stages of development. Therefore, all considered specimens are mature.

Sample size varied between 25 and 42 individuals (Tab. I). According to Reist (1985), the limit of 25 specimens is considered to be appropriate for truss approach. Nevertheless, we opted to analyse all specimens sampled in order to have more concise results.

Shape analysis according to truss approach

The truss network system described for fish body morphometrics (Strauss and Bookstein, 1982) was used to make a network on the fish body outline. Eleven landmarks determining 23 truss elements were produced and measured (Fig. 2; Annex II). Images of fish were acquired from a fixed distance with a digital camera, and analysed using image software (Visilog, version 6.480). This software interface allows the practitioner to precisely landmark and record the X-Y coordinates of each landmark, to build the truss network.

Table I. - Sample locations of *Lithognathus mormyrus,* code, sampling date, fishing gear, number of individuals and mean standard length (M_{SL} average ± s.d.).

| Countries	Localities	Code	Date	Fishing gear	Sample size	M_{SL} (cm)
Algeria	Mellah	LM-MedW	Jul. 2009	Monofilament nets-Fish weir	25	15.55 ± 1.76
Tunisia	Bizerta	LBIZ-MedW	Nov. 2008-Jan 2009	Trammel nets	30	17.32 ± 2.08
	Ghar El Melh	LGM-MedW	Apr. 2008	Trammel nets	36	15.85 ± 1.53
	El Biban	LBIB-MedE	Jun. 2008-Jun. 2009	Fish weir	42	15.46 ± 1.6
Libya	Farwa	LFW-MedE	Feb. 2010	trammel nets	29	16.49 ± 0.97
Italy	Venice	LV-MedE	May 2010	trammel nets	26	17.66 ± 1.26
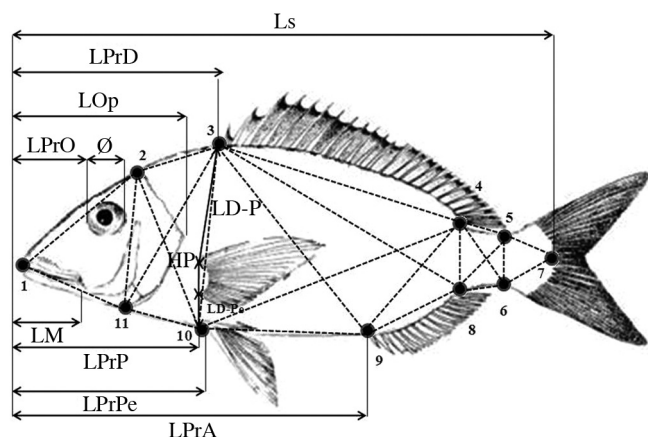
Figure 2. - Conventional linear variables and truss elements. Locations of the 11 landmarks (1-11) used to define the truss network on *L. mormyrus*. Landmarks are illustrated as black dots and truss measurements between the dots as discontinued lines. Abbreviations in Annex II.

Calibration was achieved for each specimen by measuring a known distance on a millimetre scale in each picture. All morphometric measurements were performed and analysed using the R 2.11.1 software.

Conventional linear measurements

Eleven complementary conventional measurements that document dimensions else than the outline of the body (such as orbital width, operculum length, preorbit length, snout length and others) were measured and added to truss data (Fig. 2, Annex II).

Statistical analyses

The precision of the variables (truss elements and conventional linear measurements) was tested by digitizing one specimen from each sample twenty times, and calculating the error variance for each variable.

The morphometric data were transformed into logarithm in order to increase multivariate normality (Pimentel, 1979). Size-dependent variation was removed using an allometric approach (Reist, 1985):

$$M_{trans} = \log M - \beta \,(\log SL - \log SL_{mean})$$

where M_{trans}: transformed measurement; M: original measurement; β: within-group slope regressions of $\log M$ against $\log SL$; SL: standard length of the fish; SL_{mean}: overall mean of the standard length.

After size effect removal, statistical analyses were performed for all data (truss and conventional linear measurements) in order to identify the combinations of variables that contribute to the separation between the studied lagoon samples.

Univariate analysis of variance (ANOVA) was performed to test whether the averages of each morphometric variable differed among the studied populations. In addition, the *t*-test

was established to infer if the averages of each variable are significantly different between two given samples.

To illustrate the differences or similarities between the studied samples and the contribution of each character to group separation, a Discriminant Function Analysis (DFA) was assessed. Wilk's criterion was estimated to test the significance of such discrimination for a combination of variables. Discriminant functions were used to classify individuals into samples. The classification success rate (PCS) was evaluated based on the percentage of individuals correctly assigned into its original sample. These statistical tests were performed using R 2.11.1 Software.

RESULTS

The ANOVA of 23 truss elements and 11 conventional linear measurements reveals highly significant differences (P < 0.001), between the lagoon samples, for 19 truss and 10 conventional variables (Tab. II). The variable V14, which is related to the height of the body (distance between the dorsal fin insertion and pelvic fin), is the only variable that remained stable between the different localities.

Among the five discriminant functions performed by DFA, the three first DFs explain respectively, 29%, 23% and 18%, which represent 70% of the total variation. The preorbital length is the variable that most contributes to define the first function (Tab. II). DF2 was mainly defined by the following variables: V1 (distance between the tip of the mouth and the end of the head, in the dorsal region), V25 (operculum length), V28 (predorsal length), V29 (prepelvic length), V30 (pre-anal length), and V31 (prepectoral length) (Tab. II). All these characters are head length related. The V5, related to the peduncle length, is the only variable defining DF3 (Tab. II).

Plotting DF1×DF2 highlights the discrimination between most of the Mediterranean lagoons (Fig. 3a). According to DF1, the two northern Tunisian lagoon samples (Bizerta and Ghar El Melh lagoons) are discriminated from the Mellah lagoon and from all the eastern samples (El Biban, Farwa and Venice lagoons), by the preorbital length character (LPrO) which shows, based on *t*-test results, the highest averages at Bizerta and Ghar El Melh (LBIZ and LGM) (Annex III).

Along the second discriminant function (DF2), Bizerta and Mellah on one hand clearly distinguish from Ghar El Melh, and on the other hand all three also distinguish from the eastern lagoons (El Biban, Venice, and Farwa lagoons), which have a median position along that axis. This discrimination is explained by the distance between anterior tip of snout and the end of the head and the operculum, predorsal, prepectoral, prepelvic and pre-anal lengths. All these variables are related to the length of the head. The Pairwise average comparisons reveals that Mellah lagoon specimens

Table II. - Loadings from discriminant function analysis. Univariate statistics (ANOVA). Significance levels; *: P < 0.05; **: P < 0.01; ***: P < 0.001.

Truss	Mediterranean lagoon samples			
Elements	DF1	DF2	DF3	F
V1: 1-2	0.150	0.669	0.160	23.886***
V2: 2-3	0.063	-0.027	-0.317	3.089*
V3: 3-4	0.208	-0.211	-0.096	3.316**
V4: 4-5	-0.243	-0.524	-0.153	14.093***
V5: 5-7	-0.532	-0.274	0.567	41.153***
V6: 6-7	-0.259	-0.173	0.162	9.399***
V7: 6-8	-0.104	-0.488	-0.226	13.292***
V8: 8-9	0.107	-0.344	-0.019	5.380***
V9: 9-10	-0.339	-0.114	-0.083	10.170***
V10: 10-11	0.052	0.466	0.198	8.821***
V11: 1-11	0.381	0.274	-0.135	10.340***
V12: 2-11	0.283	0.160	0.109	4.746***
V13: 3-11	-0.028	0.292	0.013	3.561**
V14: 3-10	-0.022	0.096	0.013	1.066
V15: 4-10	-0.145	-0.328	-0.107	6.756***
V16: 4-8	-0.216	-0.499	-0.252	14.284***
V17: 5-8	-0.030	-0.377	-0.216	12.291***
V18: 5-6	0.299	-0.164	0.124	7.178***
V19: 4-6	-0.202	-0.534	-0.095	13.800***
V20: 4-9	0.103	-0.528	-0.200	12.064 ***
V21: 3-9	-0.091	-0.247	-0.226	4.338***
V22: 2-10	0.316	0.176	0.089	6.272***
V23: 3-8	0.025	-0.403	-0.133	5.944***
Conventional measurements				
V24: HP	0.373	0.427	-0.402	23.407***
V25: LOp	0.260	0.763	-0.120	41.965 ***
V26: Ø	-0.138	0.362	0.301	11.352 ***
V27: LM	0.055	0.329	0.053	4.807***
V28: LPrD	0.196	0.720	-0.075	28.020***
V29: LPrPe	0.428	0.643	0.030	36.632 ***
V30: LPrA	0.172	0.619	-0.081	19.606 ***
V31: LPrP	0.271	0.717	-0.095	35.952 ***
V32: LD-P	-0.196	-0.182	-0.051	3.373**
V33: LP-Pe	0.161	-0.064	0.382	5.191***
V34: LPrO	0.915	0.315	-0.003	282.500***

(Algeria) have the smallest heads when compared to the other western samples (Bizerta and Ghar El Melh lagoons) but also compared to the eastern ones (El Biban, Farwa, and Venice lagoons), which show a tendency to cluster (Annex III).

The distinction of the Ghar El Melh from Bizerta lagoon samples also explained by DF2, seems to be defined by the head region here again, especially by the variable V1 (Distance between the tip of the mouth and the end of the head). Indeed, Ghar El Melh specimens show the highest average

compared to Bizerta lagoon specimens ($t_{LGM-LBIZ} = 3.014$, P < 0.01, ddl = 64).

The plot DF1×DF3 notably illustrates the distinction of El Biban sample from other samples notably other eastern ones along DF3, which is due to the variable V5 in relation to the caudal peduncle length (Fig. 3B). The application of the *t*-test shows that El Biban specimens have the lowest average compared to other eastern lagoon samples ($t_{LFW-LBIB} = 5.512$, P < 0.001, ddl =69; $t_{LV-LBIB} = 7.876$, P < 0.001, ddl =66).

The significance of the inter-group variability between the Mediterranean lagoon samples was proven by the estimation of Wilk's criterion (Wilk's λ = 0.001, F = 13.245, P < 0.001). The overall assignment of individuals into their original sample by DFA is 95.5% and the highest proportion of properly classified individuals into their original group is observed for Bizerta and Ghar El Melh lagoon samples where it reaches a 100% (Annex IV).

DISCUSSION

The morphometric analysis, conducted based on truss elements and complementary conventional measurements, shows a significant phenotypic heterogeneity of the striped seabream between the six different Mediterranean lagoons sampled. The variation between the western lagoons (Mellah, Bizerta and Ghar El Melh) is mainly due to the head length and dimensions. In fact, northern Tunisian samples are characterized by their high preorbital length, especially Ghar El Melh specimens, while Mellah sample shows smaller head than all others. Concerning the eastern samples (El Biban, Farwa and Venice), they globally cluster together with also a small head but with intermediate preorbital length. Finally, the populations show various peduncle shapes from shorter ones at El Biban to longer ones at Venice and Mellah.

The morphological discrepancy in the head region was highlighted in several marine fish such as carangids (Turan, 2004), labrids (Westneat, 1995; Wainwright *et al.*, 2004), gobies (Mejri *et al.*, 2012) and sparids (Sarà *et al.*, 1999; Palma and Andrade, 2002) and the influence of habitat differences is generally evoked as an explanation. It could be justified since aquatic environments present different intrinsic characteristics (hydrodynamics, turbidity, temperature, salinity, substrata, etc.) and offer various ecological niches with different diets (Hyndes *et al.*, 1997; Delariva and Agostinho, 2001). In this respect, the studied lagoon samples belong to different geographical areas (Western Mediterranean basin, Gabès Gulf in south Eastern Mediterranean basin, North Adriatic in north Eastern Mediterranean basin) with various influences (Atlantic, subtropical and subatlantic with Indo-Pacific elements) and differences especially in their hydrodynamics, physicochemical characteristics and in
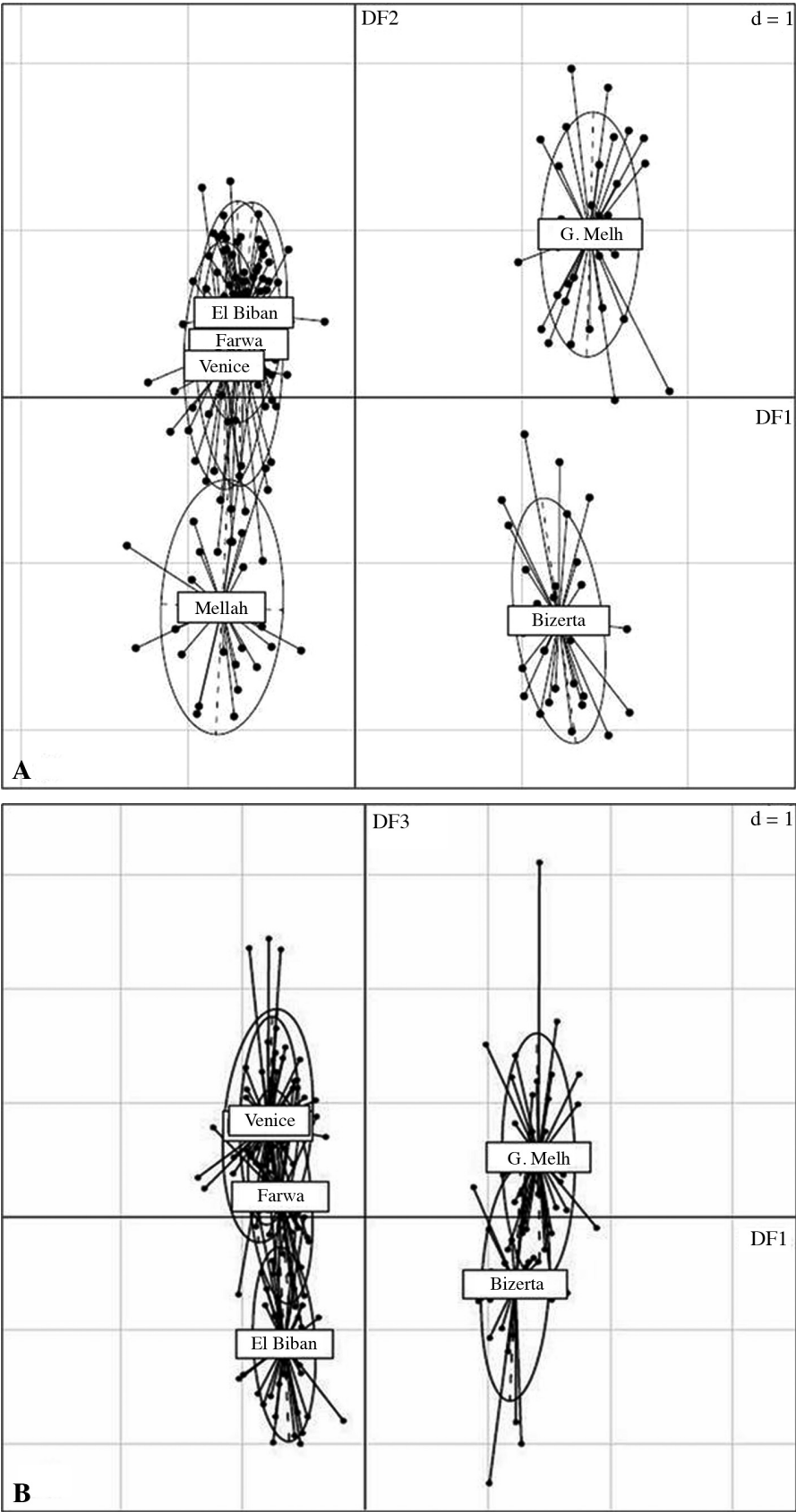
Figure 3. - FDA scores on the three first discriminant functions for the Mediterranean lagoon samples projected on FD1×FD2 plane (A) and on FD1×FD3 plane (B).

the bottom nature (Annex I) where might feature different food resources.

Indeed, demersal fish, like *Lithognathus mormyrus*, are highly mobile but very dependent of the bottoms, where they get their feeding. Thus, *L. mormyrus* usually inhabits the bottoms in search of its food. Its preferred preys vary from one environment to another. In the Gulf of Annaba (Algeria), the diet of *L. mormyrus* consists mainly of molluscs, especially bivalves, crustaceans (Mysidacea, Amphipoda, Decapoda,…) and clupeid fish are secondary preys (Harchouche *et al.*, 2005), while in the Gulf of Gabès its preferred preys are represented by crustaceans, annelids being secondary preys (Ghorbel, 1981). In addition, in the Adriatic Sea (Croatia), the diet of striped seabream is composed of eight groups of benthic animals (bivalves and gastropods molluscs, polychaetes, crustaceans decapods, copepods and amphipods, echinoderms and teleost fish) with a wide panel of size and among whom the preferred group varies with the age of the fish (Šantić *et al.*, 2010). These differences in *L. mormyrus* diet probably reflect fluctuation of prey abundance and availability in the various areas. In fact, if feeding (e.g. type, size) is a well-known factor that influences head morphology, ingestion of different prey types contributes significantly to the head shape as is the case of the salamander larvae (Walls *et al.*, 1993). Thus, further analysis of the diet of striped seabream in the studied sites would allow verifying its impact on interpopulation variation notably in the head shape.

Our results also indicate that Mellah lagoon specimens have smaller heads compared to all the remaining samples. Similar findings, concerning the particularity of Mellah environment, have been reported with other species. Indeed, Kara and Frehi (1997) have mentioned a local morphological discrimination between *Dicentrarchus labrax* of the Gulf of Annaba and those of the Mellah lagoon. Most of discriminative characters were related, as in the present work, to the anterior part of the body, mainly the head region.

In addition to these differences in the head shape, morphological discrepancies regarding the caudal peduncle length were observed. Such variation is usually related to the swimming activity, the performance, the predation pressure, and then to the hydrodynamic constraints (Poleo *et al.*, 1995; Walker, 1997; Ghalambor *et al.*, 2003; Costa and Cataudella, 2007). Although, the three eastern lagoons (El Biban, Farwa and Venice) are characterized by permanent communication with the open sea (Medhioub, 1979; Pergent and Pergent-Martini, 2000; Bellafiore *et al.*, 2008) and they are subject to large marine influences due to their wide inlets. However, the communication with the open sea of Farwa lagoon and that of Venice is much broader than that of El Biban. In addition, when considering the differences in hydrodynamic (Annex. I), the Venice lagoon is characterized by an important semidiurnal tidal regime with a range of about ± 0.7 m, thus more pronounced than El Biban regime.

Water exchanges between Venice Lagoon with the sea may reach 8000 m^3 s^{-1} and typically amounts to about one-third of the total lagoon volume per tidal cycle (Gačić *et al.*, 2004; Bellafiore *et al.*, 2008). These findings could explain the differences in caudal peduncle region between Venice specimens (which have long caudal peduncle) compared to El Biban ones. Despite the lack of data for Farwa lagoon, such an explanation can be applied to this area where the wide extend of the exchange area (inlet ≈ 3 km) can highlight the greater marine influence (Smart *et al.*, 2006) compared to El Biban lagoon (width of the main inlet ≈ 400 m) (Guélorget *et al.*, 1982). The lengthening of the caudal peduncle seems to be developed as a mechanism of adaptation to improve swimming ability in strong hydrodynamic environments.

As for the variation in the caudal peduncle length between Bizerta, Ghar El Melh and El Biban lagoons, it can be explained by the differences among their respective average depths. Indeed, Bizerta lagoon is the deepest one (≈ 7 m). Therefore fish that feed on the bottom, as *L. mormyrus*, need a better swimming performance than their congeners living in shallow lagoons such as Ghar El Melh (≈ 0.8 m) and El Biban (≈ 4 m) (Annex I). The same hypothesis may be retained to explain the differences between Mellah (≈ 3.5 m) and Ghar El Melh (≈ 0.8 m) lagoons. In contrast, the difference in caudal peduncle length between Mellah and El Biban lagoons seems to be associated to another factor. Indeed, Mellah lagoon is a small confined where eutrophication generates an increase in turbidity. Yet, previous studies, concerning the turbidity effects, have revealed that increasing turbidity often leads to substantive community changes through altering trophic dynamics (Van de Meutter *et al.*, 2005). Thus, the outcomes of predator-prey interactions are highly influenced by levels of turbidity (Gregory, 1993; Bonner and Wilde, 2002; Lehtiniemi *et al.*, 2005; Zamor and Grossman, 2007). So, in high turbidity conditions, the detection and reaction distance of both participants (prey and predators) can likely diminished as turbidity increases. Therefore, search time of prey tended to increase, due to the relative scarcity of prey and the significant predation pressure, forcing predators to have a better swimming performance (Vogel and Beauchamp, 1999; Quesenberry *et al.*, 2007). Such findings can suggest that Mellah specimens seem to be adapted to have the high mobility required to maximize encounter rates with patchily distributed prey.

In this study, we showed the existence of morphological differences between the Mediterranean lagoonal populations of *L. mormyrus*. The phenotypic plasticity observed can be related with variation in selective pressures of their respective habitats: variety of diets, niches, environmental conditions (Mayr, 1963; Swain and Foot, 1999).

Indeed, continuous exposure to the physical and biotic properties of an individual's habitat is known to usually induce a phenotypic response in that individual (Páez *et al.*,

2008). In the same context, Kara and Frehi (1997) inferred that lagoon organisms, either if they are permanent or temporary residents, can show adaptive strategies in response to multiple environmental conditions.

However, the expression of many phenotypic traits can be explained not only by the local environment factors, but also by the genetic compound, and/or the interaction between genes and environment (Cabral *et al.*, 2003; Favaloro and Mazzola, 2006; Bahri-Sfar and Ben Hassine, 2009). So far, we do not have sufficient data on the genetic structure of these Mediterranean lagoon samples to exclude totally that genetic control of the different morphologies. Therefore, our results need further genetic analysis to highlight the real contribution of genetic and plastic response to the environmental components in the establishment of these morphologies. Further research is needed to have a clearer understanding of the likely complex relationship between energetic swimming, habitat structure, diet, predation process, and morphological variation in this species.

REFERENCES

AMOS C.L., UMGIESSER G., TOSI L. & TOWNEND I., 2010. - The coastal morphodynamics of Venice lagoon, Italy: an introduction. *Cont. Shelf Res.*, 30: 837-846.

BAHRI-SFAR L. & BEN HASSINE O.K., 2009. - Clinal variations of discriminative meristic characters of sea bass. *Dicentrarchus labrax* (Moronidae, Perciformes) populations on Tunisian coasts. *Cybium*, 33: 211-218.

BARNES R.S.K., 1980. - Coastal Lagoons. 106 p. Cambridge: Cambridge Univ. Press.

BAUCHOT M.L. & HUREAU J.C., 1986. - Sparidae. *In*: Fishes of the north-eastern Atlantic and the Mediterranean (Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielsen J. & Tortonese E., eds.), Vol 2, pp. 883-907. Paris: UNESCO.

BAUCHOT M.L. & HUREAU J.C., 1990. - Sparidae. *In*: Check-List of the Fishes of the eastern tropical Atlantic (CLOFETA), Vol. 2 (Quéro J.C., Hureau J.C., Karrer C., Post A. & Saldanha L., eds.), pp. 790-812. Lisbon: JNICT; Paris: SEI & UNESCO.

BÉJAOUI B., HARZALLAH A., MOUSSA M., CHAPELLE A. & SOLIDORO C., 2008. - Analysis of hydrobiological pattern in the Bizerte lagoon (Tunisia). *Est. Coast. Shelf Sci.*, 80(1): 121-129.

BELLAFIORE D., UMGIESSER G. & CUCCO A., 2008. - Modeling the water exchanges between the Venice Lagoon and the Adriatic Sea. *Ocean Dynam.*, 58 (5): 397-413.

BEN HASSINE O.K., 1983. - Les copépodes parasites de poissons Mugilidés en Méditerranée occidentale (côte française et tunisienne). Morphologie, bio-écologie, cycle évolutif. Thèse de Doctorat d'État. 452 p. USTL, Montpellier, France.

BONNER T.H. & WILDE G.R., 2002. - Effects of turbidity on prey consumption by prairie stream fishes. *Trans. Am. Fish. Soc.*, 131: 1203-1208.

BRADAI M.N., QUIGNARD J.P., BOUAIN A., JARBOUI O., OUANNES GHORBEL A., BEN ABDALLAH L., ZAOUALI J. & BEN SALEM S., 2004. - Ichtyofaune autochtone et exotique des cotes tunisiennes: recensement et biogeographie. *Cybium*, 28(4): 315-328.

BRAHIM M., BEJAOUI B. & ATOUI A., 2008. - Étude de l'hydrodynamique sédimentaire de la lagune de Bizerte. *Bull. Inst. Natl. Sci. Tech. Mer Salammbô*, 35: 149-160.

CABRAL H.N., MARQUES J.F., REGO A.L., CATARINO A.I., FIGUEIREDO J. & GARCIA J., 2003. - Genetic and morphological variation of *Synaptura lusitanica* Capello, 1868, along the Portuguese coast. *J. Sea Res.*, 50: 167-175.

CAPAPÉ C., GUÉLORGET O., QUIGNARD J.P., EL ABED A., ZAOUALI J. & BENSOUISSI J., 2004. - The Elasmobranch species from the Bahiret El Biban (Southern Tunisia, Central Mediterranean): a survey. *Ann. Ser. Hist. Nat.*, 14(1): 19-28.

CARVALHO G.R., 1993. - Evolutionary aspects of fish distribution: genetic variability and adaptation. *J. Fish. Biol.*, 43(A): 53-73.

CHAOUI L., KARA M.H., FAURE E. & QUIGNARD J.P., 2006. - L'ichtyofaune de la lagune du Mellah (Algérie Nord-Est) : diversité, production et analyse des captures commerciales. *Cybium*, 30(2): 123-132.

CHEVERUD J.M., 1988. - A comparison of genetic and phenotypic correlations. *Evolution*, 42: 958-968.

ÇOBAN D., SAKA F. & FIRAT K., 2008. - Morphometric comparison of cultured and lagoon caught gilthead seabream (*Sparus aurata* L. 1758*)*. *Turk. J. Zool.*, 32: 337-341.

COSTA C. & CATAUDELLA S., 2007. - Relationship between shape and trophic ecology of selected species of Sparids of the Caprolace coastal lagoon (Central Tyrrhenian Sea). *Environ. Biol. Fish.*, 78 (2): 115-123.

DELARIVA R.L. & AGOSTINHO A.A., 2001. - Relationship between morphology and diets of six neotropical loricariids. *J. Fish. Biol.*, 58: 832-847.

ELLIOTT M., 2002. - Introduction. *In*: Fishes in Estuaries (Elliott M. & Hemingway K.L., eds), pp. 1-9. Oxford: Blackwell Science.

EMRE Y., BALIK İ., SÜMER Ç., SKAY D.A. & YEŞILÇIMEN H.O., 2010. - Age, growth, length-weight relationship and reproduction of the striped seabream (*Lithognathus mormyrus* L., 1758 (Sparidae) in the Beymelek Lagoon (Antalya, Turkey). *Turk. J. Zool.*, 34: 93-100.

FAVALORO E. & MAZZOLA A., 2006. - Meristic character counts and incidence of skeletal anomalies in the wild *Diplodus puntazzo* (Cetti, 1777) of an area of the south-eastern Mediterranean Sea. *Fish. Physiol. Biochem.*, 32: 159-166.

GAČIĆ M., MAZZOLDI A., KOVAČEVIĆ V., MANCERO MOSQUERA I., CARDIN V., ARENA F. & GELSI G., 2004. - Temporal variations from tidal to seasonal scales of water fluxes between the Venetian Lagoon and the open sea. *J. Mar. Syst.*, 51: 33-47.

GHALAMBOR C.K., WALKER J.A. & REZNICK D.N., 2003. - Multi-trait selection, adaptation, and constraints on the evolution of burst swimming performance. *Integr. Comp. Biol.*, 43: 431-438.

GHORBEL M., 1981. - Contribution à l'étude morphologique et biologique des poissons des genres *Pagellus* et *Lithognathus* de Tunisie ; étude dynamique préliminaire du pageau dans le golfe de Gabès. DEA. 139 p. Univ. Tunis El Manar, Tunisie.

GIORDANI SOIKA A., 1978. - Importanza del Delta padano nell ecologia e biogeografia delle coste italiane dell Adriatico. *Boll. Mus. Ven.*, 29(Suppl.): 31-42.

GREGORY R.S., 1993. - Effect of turbidity on the predator avoidance behaviour of juvenile chinook salmon (*Oncorhynchus tshawytscha*). *Can. J. Fish. Aquat. Sci.*, 50: 214-246.

GUÉLORGET O. & PERTHUISOT J.P., 1983. - Le domaine paralique. Expressions géologiques, biologiques et économiques du confinement. Travaux du laboratoire de géologie, 16: 1-136.

GUÉLORGET O. & PERTHUISOT J.P., 1989. - The paralic realm geological, biological and economic expressions of confinement. Report prepared for the Mediterranean Regional Aquaculture Project, 142 p. Rome: FAO.

GUÉLORGET O., FRISONI G.F. & PERTHUISOT J.P., 1982. - Contribution à l'étude biologique de la Bahiret El Bibane, bassin paralique du Sud-Est tunisien. *Mem. Soc. Geol. Fr.*, NS, 144: 173-186.

GUÉLORGET O., FRISONI G.F., XIMENES M.C. & PERTUISOT J.P., 1989. - Expressions biogéologiques du confinement dans une lagune méditerranéenne : le lac Mellah (Algérie). *Rev. Hydrobiol. Trop.*, 22(2): 87-99.

HAMDI H., JEDIDI N., YOSHIDA M., MOSBAHI M. & GHRABI A., 2002. - Some physico-chemical properties of lake Bizerte sediments. Study on the environment pollution of Mediterranean coastal lagoons in Tunisia. Initial report, pp. 49-54.

HAMMAMI I., BAHRI-SFAR L., KAOUÈCHE M. & BEN HASSINE O.K., 2007. - Genetic characterization of striped sea bream (*Lithognathus mormyrus*) populations on both sides of a boundary area between eastern and western Mediterranean basins. *Cybium*, 31(2):143-147.

HAMMAMI I., BAHRI-SFAR L. & BEN HASSINE O.K., 2011. - Morphological variations of striped seabream, *Lithognathus mormyrus*, populations along the Tunisian coast. *J. Mar. Biol. Ass. U.K.*, 91: 1261-1271.

HARCHOUCHE K., MAURIN C. & QUÉRO J.C., 2005. - Inventaire des proies ingérées par le marbré *Lithognathus mormyrus* (Linnaeus, 1758) (Pisces : Perciformes : Sparidae) dans la baie d'Alger et d'Annaba. *Ann. Soc. Sci. Nat. Charente-Mar.*, 9(5): 491-502.

HOSSAIN M.A.R., NAHIDUZZAMAN M.D., SAHA D., KHANAM M.U.H. & ALAM M.S., 2010. - Landmark-based morphometric and meristic variations of the endangered carp, kalibaus *Labeo calbasu*, from stocks of two isolated rivers, the Jamuna and Halda, and a hatchery. *Zool. Stud.*, 49(4): 556-563.

HYNDES G.A., PLATELL M.E. & POTTER I.C., 1997. - Relationships between diet and body size, mouth morphology, habitat and movement of six sillaginid species in coastal waters: implications for resource partitioning. *Mar. Biol.*, 128: 585-598.

KARA M.H. & FREHI H., 1997. - Étude biométrique du loup *Dicentrarchus labrax* du golfe d'Annaba. Différenciation d'une population lagunaire voisine. *J. Rech. Océanogr.*, 22(2): 45-50.

KJERFVE B., 1994. - Coastal lagoons. *In*: Coastal Lagoons Processes (Kjerfve B., ed.), Series 60, Chapter 1, pp. 1-8. Amsterdam: Elsevier Science Publishers.

LEHTINIEMI M., ENGSTROM-OST J. & VIITASALO M., 2005. - Turbidity decreases anti-predator behaviour in pike larvae, *Esox lucius*. *Environ. Biol. Fish.*, 73: 1-8.

LEMOALLE J. & VIDY G., 1984. - Conditions de milieu et pêche dans la lagune hypersaline d'El Bibane (Tunisie). *Stud. Rev. CGFM*, 61(1):175-195.

MALAVASI S., FIORIN R., FRANCO A., FRANZOI P., GRANZOTTO A., RICCATO F. & MAINARDI D., 2004. - Fish assemblages of Venice lagoon shallow waters: an analysis based on species, families and functional guilds. *J. Mar. Syst.*, 51: 19-31.

MATIĆ-SKOKO S., PEHARDA M., PALLAORO A., CUKROV M. & BAŽDARIĆ B., 2007. - Infralittoral fish assemblages in the Zrmanja estuary, Adriatic Sea. *Acta Adriat.*, 48(1): 45-55.

MAYR E., 1963. - Animal species and evolution. 797 p. Cambridge: Belknap Press of Harvard Univ. Press.

MCHUGH J.L., 1967. - Estuarine nekton. *In*: Estuaries (Lauff G.H., ed.), Pub. 83, pp. 581-620. Washington, DC: AAAS.

MEDHIOUB K., 1979. - La Bhiret El Biban, étude géochimique et sédimentologique d'une lagune du Sud-Est tunisien. Trav. Labo. Géol. 13, 150 p. Paris: Presses de l'École normale supérieure.

MEDHIOUB K., SAUBADE A., ZAOUALI J., GUELORGET O. & PERTHUISOT J.P., 1986. - Évolution paléogéographique de la Bahiret El Biban (S.E. tunisien) depuis 5000 ans d'après les variations de la macrofaune fossile et quelques données géochimiques. *Bull. Soc. Géol. Fr.*, 8: 131-138.

MEJRI R., LO BRUTTO S., HASSINE N., ARCULEO M. & BEN HASSINE O.K., 2012. - Overlapping patterns of morphometric and genetic differentiation in the Mediterranean goby *Pomatoschistus tortonesei* Miller, 1968 (Perciformes, Gobiidae) in Tunisian lagoons. *Zoology*, 115: 239-244.

MONTEIRO P., BENTES L., COELHO R., CORREIA C., ERZINI K., G. LINO P., RIBEIRO J. & M.S. GONÇALVES J., 2010. - Age and growth, mortality and reproduction of the striped seabream, *Lithognathus mormyrus* Linnaeus, 1758, from the south coast of Portugal (Algarve). *Mar. Biol. Res.*, 6(1): 53-65.

MOUSSA M., BACCAR L. & BEN KHEMIS R., 2005. - La lagune de Ghar El Melh: Diagnotic écologique et perspectives d'aménagement hydraulique. *Rev. Sci. Eau.*, 18: 13-26.

NEIFAR L., 2001. - Biodiversité et évolution des Plathelminthes parasites des Elasmobranches. Thèse de Doctorat. 326 p. Univ. Tunis El Manar, Tunisie.

PÁEZ D.J., HEDGER R., BERNATCHEZ L. & DODSON J.J., 2008. - The morphological plastic response to water current velocity varies with age and sexual state in juvenile Atlantic salmon, *Salmo salar*. *Freshw. Biol.*, 53(8): 1544-1554.

PALMA J. & ANDRADE J.P., 2002. - Morphological study of *Diplodus sargus*, *Diplodus puntazzo* and *Lithognathus mormyrus* (Sparidae) in the Eastern Atlantic and Mediterranean Sea. *Fish. Res.*, 57: 1-8.

PALUMBI S.R., 1994. - Genetic divergence, reproductive isolation, and marine speciation. *Annu. Rev. Ecol. Syst.*, 25: 547-572.

PERGENT G. & PERGENT-MARTINI C., 2000. - Field Study in Libya. Study of the vegetation in the lagoon of Farwà. Regional Activities Centre for Specially Protected Areas and University of Corsica / contract N°38/99: 1-47 + Annexes.

PÉREZ-RUZAFA A., MOMPEÁN M.C. & MARCOS C., 2007. - Hydrographic, geomorphologic and fish assemblage relationships in coastal lagoons. *Hydrobiologia*, 577: 107-125.

PIMENTEL R.A., 1979. - Morphometrics: the multivariate analysis of biological data. Dubuque, IA: Kendall/Hunt Publishing Company.

POLEO A.B.S., ØXNEVAD S.A., ØSTBYE K., HEIBO E., ANDERSEN R.A. & VOLLESTAD L.A., 1995. - Body morphology of crucian carp *Carassius carassius* in lakes with or without piscivorous fish. *Ecography*, 18:225-229.

QUESENBERRY N.J., ALLEN P.J. & CECH J.J., 2007. - The influence of turbidity on three-spined stickleback foraging. *J. Fish Biol.,* 70: 965-972.

REIST J.D., 1985. - An empirical evaluation of several univariate methods that adjust for size variation in morphometric data. *Can. J. Zool.*, 63: 1429-1439.

ROBY D., LAMBERT J.D. & SEVIGNY J.M., 1991. - Morphometric and electrophoretic approaches to discrimination of capelin (*Mallotus villosus*) populations in the estuary and Gulf of St. Lawrence. *Can. J. Fish. Aquat. Sci.,* 48: 2040-2050.

RYMAN N., LAGERCRANTZ U., ANDERSSON L., CHAKRABORTY R. & ROSENBERG R., 1984. - Lack of correspondence between genetic and morphologic variability patterns in Atlantic herring (*Clupea harengus*). *Heredity,* 53: 687-704.

SACCHI C.F., BIANCHI C.N., MORRI C., OCCHIPINTI AMBROGI A. & SCONFIETTI R., 1985. - Biogéographie des lagunes côtières nord-adriatiques. *Rapp. Comm. Int. Mer Médit.*, 29(4): 163-166.

ŠANTIĆ M., PALADIN A. & ELEZ G., 2010. - Diet of striped sea bream *Lithognathus mormyrus* (Sparidae) from eastern central Adriatic Sea. *Cybium*, 34(4): 345-352.

SARÀ M., FAVAROLO E. & MAZZOLA A., 1999. - Comparative morphometrics of sharpsnout seabream (*Diplodus puntazzo* Cetti, 1777) reared in different conditions. *Aquacult. Eng.*, 19: 195-209.

SILVA A., 2003. - Morphometric variation among sardine (*Sardina pilchardus*) populations from the northeastern Atlantic and the western Mediterranean. *ICES J. Mar. Sci.,* 60: 1352-1360.

SMART M., ESSGHAIER M.F., ETAYEB K., HAMZA A., AZAFZAF H., BACCETTI N., DEFOS DU RAU P. & DLENSI H., 2006 - Wetlands and wintering waterbirds in Libya, January 2005 and 2006. *Wildfowl*, 56: 172-191.

SOLIDORO C., BANDELJ V., AUBRY BERNARDI F. *et al.* [18 authors], 2010. - Response of Venice Lagoon ecosystem to natural and anthropogenic pressures over the last 50 years. *In*: Coastal Lagoons: Critical Habitats of Environmental Change (Kennish M.H.K. & Paerl H., eds), pp. 483-512. Boca Raton: CRC Press.

STRAUSS R.E. & BOOKSTEIN F.L., 1982. - The Truss: body form reconstitution in morphometrics. *Syst. Zool.*, 31: 113-135.

SUAU P., 1970. - Contribución al estudio de la biología de *Lithognathus* (= *Pagellus*) *mormyrus* L. (Peces esparidos). *Inv. Pesq.*, 34: 237-265.

SWAIN D. & FOOTE C.J., 1999. - Stocks and chameleons: the use of phenotypic variation in stock identification. *Fish. Res.*, 43: 113-128.

TOLOMIO C., MOSCHIN E. & MORO I., 2006. - Phytoplancton de la lagune de Venise. II. Bassin central (avril 1989-mars 1990). *Lavori - Soc. Ven. Sci. Nat.*, 31: 25-35.

TURAN C., 2004. - Stock identification of Mediterranean horse mackerel *(Trachurus mediterraneus)* using morphometric and meristic characters. *ICES J. Mar. Sci.*, 61: 774-781.

TURAN C., ORAL M., OZTURK B. & DUZGUNES E., 2006. - Morphometric and meristic variation between stocks of bluefish (*Pomatomus saltatrix*) in the Black, Marmara, Aegean and northeastern Mediterranean Seas. *Fish. Res.*, 79: 139-147.

UIBLEIN F., 1995. - Morphological variability between populations of *Neobythites stefanovi* (Pisces: Ophidiidae) from deep Red Sea and Gulf of Aden. *Mar. Ecol. Prog. Ser.,* 124: 23-29.

UNESCO, 1981. - Coastal lagoons research, present and future. *Unesco Tech. Pap. Mar. Sci.*, 32: 51-79.

VAN DE MEUTTER F., STOKS R. & DE MEESTER L., 2005. - The effect of turbidity state and microhabitat on macroinvertebrate assemblages: a pilot study of six shallow ponds. *Hydrobiologia*, 542: 379-390.

VOGEL J.L. & BEAUCHAMP D.A., 1999. - Effects of light, prey size, and turbidity on reaction distances of lake trout (*Salvelinus namaycush*) to salmonid prey. *Can. J. Fish. Aquat. Sci.*, 56: 1293-1297.

WAINWRIGHT P.C., BELLWOOD D.R., WESTNEAT M.W., GRUBICH J.R. & HOEY A.S., 2004. - A functional morphospace for the skull of labrid fishes: patterns of diversity in a complex biomechanical system. *Biol. J. Linn. Soc.*, 82: 1-25.

WALKER J.A., 1997. - Ecological morphology of lacustrine threespine stickleback *Gasterosteus aculeatus* L. (Gasterosteidae) body shape. *Biol. J. Linn. Soc.,* 61:3-50.

WALLS S.C., BELANGER S.S. & BLAUSTEIN A.R., 1993. - Morphological variation in a larval salamander: dietary induction of plasticity in head shape. *Oecologia*, 96(2): 162-168.

WESTNEAT M.W., 1995. - Feeding, function, and phylogeny: analysis of historical biomechanics and ecology in labrid fishes using comparative methods. *Syst. Biol.*, 44: 361-383.

WIMBERGER P.H., 1991. - Plasticity of jaw and skull morphology in the neotropical cichlids *Geophagus brasiliensis* and *G. steindachneri*. *Evolution*, 45: 1545-1563.

WIMBERGER P.H., 1992. - Plasticity of fish body shape. The effects of diet, development, family and age in two species of *Geophagus* (Pisces: Cichlidae). *Biol. J. Linn. Soc.*, 45: 197-218.

ZAMOR R.M. & GROSSMAN G.D., 2007. - Turbidity affects foraging success of drift-feeding rosyside dace (*Clinostomus funduloides*). *Trans. Am. Fish. Soc.,* 136: 167-176.

ZAOUALI J., 1984. - La pêche dans les lagunes tunisiennes : le lac de Bizerte : Tunisie septentrionale. *Stud. Rev. CGPM*, 61(1): 297-321.

Annex I. - Environment parameters of the six studied lagoons.

	Mellah	Bizerta	Ghar El Melh	El Biban	Farwa	Venice
Geographic coordinates	36°53'N-8°19'E	37°13'N-9°51'E	37°10'N-10°11'E	33°16'N-11°17'E	33°05'N-11°44'E	45°26'N-12°18'E
Area	8.65 km^2 (Guélorget *et al.*, 1989)	128 km^2 (Béjaoui *et al.*, 2008)	28.5 km^2 (Moussa *et al.*, 2005)	230 km^2 (Capapé *et al.*, 2004)	31 km^2 (Pergent and Pergent-Martini, 2000)	550 km^2 (Solidoro *et al.*, 2010)
Mean depth	3.5 m (Guélorget *et al.*, 1989)	7 m (Béjaoui *et al.*, 2008)	0.8 m (Moussa *et al.*, 2005)	4 m (Lemoalle and Vidy, 1984 ; Medhioub *et al.*, 1986)	0.5-2.5 m (Pergent and Pergent-Martini, 2000)	1 m (Solidoro *et al.*, 2010)
Temperature	10°C-30°C (Chaoui *et al.*, 2006)	11.5°C-29.5°C (Béjaoui *et al.*, 2008)	10.3 °C-29.7°C (Ben Hassine, 1983)	13°C-30°C (Neifar, 2001)	10°C-29°C (Pergent and Pergent-Martini, 2000)	3°C-24°C (Solidoro *et al.*, 2010)
Salinity	25.4‰-34.8‰ (Chaoui *et al.*, 2006)	32‰-36.8‰ (Béjaoui *et al.*, 2008)	36‰-51‰ (Moussa *et al.*, 2005)	45‰-50‰ (Neifar, 2001)	38.5‰-44‰ (Pergent and Pergent-Martini, 2000)	21.5 ‰-38‰ (Tolomio *et al.*, 2006)
Area of exchange	Chanel Length: 900 m Width: 10 m Depth: 0.6 m (Guélorget *et al.*, 1989)	Chanel Length: 7 km Width: 300 m Depth: 12 m (Brahim *et al.*, 2008)	Inlet Width: 85 m Depth: 2.5 m (Moussa *et al.*, 2005)	Inlets Width of the main inlet: 400 m Depth of the main inlet: 14 m (Guélorget *et al.*, 1982; Medhioub *et al.*, 1986)	Inlet Width: 3 km (Smart *et al.*, 2006)	Inlets Lido inlet (width: 800 m depth: 14m) Malamocco inlet (width: 400 m; depth: 17m) Chioggia inlet (width: 400 m; depth: 8m) (Solidoro *et al.*, 2010)
Bottom types	Muddy (Guélorget *et al.*, 1989)	Muddy (Hamdi *et al.*, 2002)	Muddy (Moussa *et al.*, 2005)	Sandy (Medhioub *et al.*, 1986)	Sandy (Pergent and Pergent-Martini, 2000)	Sandy (Amos *et al.*, 2010)
Vegetation	*Zostera noltii* *Ruppia maritima* *Ulva* sp. *Enteromorpha* sp. (Algae are the most dominants) (Guélorget *et al.*, 1989)	*Cymodocea nodosa* *Caulerpa prolifera* *Ulva lactuca* (Algae are the most dominants) (Zaouali, 1984)	*Ruppia cirrhosa* *Cladophora* sp. (Algae are the most dominants) (Moussa *et al.*, 2005)	*Zostera noltii* *Cymodocea nodosa* *Caulerpa prolifera* *Lithothamnium* sp. (Phanerogams are the most dominants) (Guélorget *et al.*, 1982)	*Cymodocea nodosa* *Posidonia oceanica* *Caulerpa prolifera* (Phanerogams are the most dominants) (Pergent and Pergent-Martini, 2000)	*Zostera noltii* *Zostera marina* *Cymodocea nodosa* Ulvaceae (Phanerogams are the most dominants) (Amos *et al.*, 2010; (Solidoro *et al.*, 2010)

	Mellah	Bizerta	Ghar El Melh	El Biban	Farwa	Venice
Geographic coordinates	36°53'N-8°19'E	37°13'N-9°51'E	37°10'N-10°11'E	33°16'N-11°17'E	33°05'N-11°44'E	45°26'N-12°18'E
Tide	Isolated from marine currents (hydrological isolation and high confinement) (Guélorget *et al.*, 1989)	0.02-0.13 m (Mejri *et al.*, 2012)	0.08-0.22 m (Moussa *et al.*, 2005)	± 0.5 m (max ≈ 1 m) (Lemoalle and Vidy, 1984)	Lack of data	± 0.70 m (max ≈ 1.93) (Solidoro *et al.*, 2010)

Annex II. - Description of the truss and conventional variables.

	Description of measurements
Variables	**Truss**
V1: 1-2	Distance between the tip of the mouth and end of the head, in the dorsal region
V2: 2-3	Distance between the end of the head and dorsal fin insertion
V3: 3-4	Length of dorsal fin base
V4: 4-5	Distance between the posterior insertion of dorsal fin and maximum curvature of the peduncle in dorsal region
V5: 5-7	Distance between the maximum curvature and end of the peduncle, in the dorsal region
V6: 6-7	Distance between the maximum curvature and end of the peduncle, in the ventral region
V7: 6-8	Distance from the posterior anal fin to maximum curvature in ventral region
V8: 8-9	Length of anal fin base
V9: 9-10	Distance between the pelvic fin insertion and anal fin
V10: 10-11	Distance between the pelvic fin insertion and end of the head, in the ventral region
V11: 1-11	Distance between the tip of the mouth and end of the head, in the ventral region
V12: 2-11	Distance between the end of the head, in the dorsal region, and end of the head, in the ventral region
V13: 3-11	Distance between the dorsal fin insertion and end of the head in ventral region
V14: 3-10	Distance between the dorsal fin insertion and pelvic fin
V15: 4-10	Distance between the anterior insertion of pelvic fin and posterior dorsal fin
V16: 4-8	Distance between the posterior insertions of pelvic and dorsal fins
V17: 5-8	Distance from the posterior anal fin to maximum curvature in dorsal region
V18: 5-6	Width of peduncle
V19: 4-6	Distance between the posterior insertion of dorsal fin and maximum curvature of the peduncle in ventral region
V20: 4-9	Distance between the posterior insertion of dorsal fin and anterior anal fin
V21: 3-9	Distance between the anterior insertions of dorsal and anal fins
V22: 2-10	Distance between the pelvic fin insertion and end of the head in dorsal region
V23: 3-8	Distance between the anterior insertion of dorsal fin and posterior anal fin
	Conventional
V24: HP	Height of the pectoral fin
V25: LOp	Operculum length
V26: Ø	Orbital width
V27: LM	Snout length
V28: LPrD	Pre-dorsal length
V29: LPrPe	Pre-pelvic length
V30: LPrA	Pre-anal length
V31: LPrP	Pre-pectoral length
V32: LD-P	Distance between the dorsal fin insertion and pectoral fin
V33: LP-Pe	Distance between the pectoral fin insertion and pelvic fin
V34: LPrO	Pre-orbit length

Annex III. - Matrix of the *t*-test for the truss and conventional variables, which contribute to the discrimination between the Mediterranean lagoon samples. Significance levels; *: P < 0.05; **: P < 0.01; ***: P < 0.001.

	LBIZ-MW	LGM-MW	LBIB-ME	LFW-ME	LV-ME
	V1:1-2				
	-2.422*	-2.975**	-0.891	-2.849**	-5.069***
	LOp				
	-3.013**	-4.430***	-2.625*	-3.402***	-5.260***
	LprP				
LM-MW	-2.777**	-4.060***	-2.102*	-3.170**	-4.558***
	LPrPe				
	-3.450***	-3.905***	-1.298	-3.264**	-5.292***
	LPrA				
	-3.658***	-2.079*	-0.856	-3.218**	-5.836***
	V5:5-7				
	0.987	4.620***	4.752***	-0.814	-3.478***
	LM-MW	LGM-MW	LBIB-ME	LFW-ME	LV-ME
	LPrO				
LBIZ-MW	8.313***	-1.417	9.10***	7.183***	5.449***
	V5:5-7				
	0.987	3.530***	3.724***	-1.995*	-4.574***
	LBIZ-MW	LM-MW	LBIB-ME	LFW-ME	LV-ME
LGM-MW	LPrO				
	1.417	10.902***	11.999***	10.040***	7.993***

Annex IV. - Correct classification of individuals into their original group. (LM-MW: Mellah lagoon; LBIZ-MW: Bizerta lagoon; LGM-MW: Ghar El Melh lagoon; LBIB-ME: El Biban lagoon; LFW-ME: Farwa lagoon and LV-ME: Venice lagoon).

Samples	LM–MW	LBIZ–MW	LGM–MW	LBIB–ME	LFW–ME	LV–ME
LM–MW	96	–	–	–	–	4
LBIZ–MW	–	100	–	–	–	–
LGM–MW	–	–	100	–	–	–
LBIB–ME	0	0	–	95	3	2
LFW–ME	–	–	–	10	90	–
LV–ME	–	–	–	4	4	92